DESIGN OF A TRAPPING SYSTEM FOR MONITORING THE SPATIO-TEMPORAL OCCURRENCE OF TSETSE (GLOSSINA SPP.)

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SVILUPPO DI UN SISTEMA DI TRAPPOLE PER IL MONITORAGGIO DELLA MOSCA TSÉ-TSÉ (*GLOSSINA* SPP.)

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Ricevuto 3 aprile 2005, accettato 7 dicembre 2005

Abstract
The deployment of 4 odour baited traps per km^2 is used as a standard in tsetse control projects and was used at two sites, Luke and Asossa, in Ethiopia. The so-obtained data were used to build maps of tsetse distribution and to identify areas with increased fly densities, referred to as *hot spot*. To render the control system more efficient, a method that allowed to optimise monitoring scheme, by reducing the number of traps and maintaining the previously reached levels of tsetse occurrence, was here described. From the original trap design, reduced trap arrangements were obtained, decreasing the number of traps from 33% to 66%. Variogram analysis and kriging interpolation of tsetse catches were performed and results obtained from reduced and complete arrangements were compared. At both sites, the geostatistical analysis showed that reliable information on spatio-temporal tsetse occurrences can be obtained by using every second trap resulting to a decrease in labour costs. Moreover, the method allowed detection of hot spots similar to the ones detected with the standard method. The remaining 50% of the traps used in the standard deployment strategy could be used for either extending the area under monitoring or for hot spot control purposes. The design and implementation of a cost-efficient monitoring system is the first step in an adaptive tsetse management system. This system has been tested at the Luke site where it resulted to cost-efficient tsetse control trap deployment, reduction in tsetse occurrences and disease prevalence in cattle, and increase in cattle productivity expressed as milk production, calving rates, and in areas being ploughed.

Keywords: Adaptive Management, geostatistics, mapping, Ethiopia.

Riassunto
I casi presentati rientrano in un piano di "Adaptive Management" per il miglioramento delle condizioni di salute degli animali domestici, attraverso il controllo delle popolazioni di mosca tsé-tsé (Glossina spp.), vettore di gravi malattie, nei territori di Luke e Asossa, in Etiopia. Per il monitoraggio del dittero, si è allestita una rete di trappole odorose e i dati ottenuti sono stati impiegati nella costruzione di mappe di distribuzione spaziale, per individuare le aree ad alta densità di cattura (hot spot). In tale contesto, si è voluto valutare l'effetto che una diminuzione delle trappole di monitoraggio determina sulla distribuzione degli hot spot *evidenziati dalle mappe. Allo scopo, dal disegno sperimentale adottato, si sono ricavati nove differenti pattern spaziali, ottenuti riducendo il numero delle trappole in un intervallo compreso tra il 33% e il 66%. Attraverso il calcolo dei variogrammi e l'interpolazione dei dati tramite kriging è stata individuata la disposizione delle trappole in grado di fornire il miglior risultato. Per entrambi i siti, una riduzione del 50% ha fornito le indicazioni migliori e per tale motivo è stata scelta nelle successive operazioni di monitoraggio. Da tali risultati, a Luke sono state posizionate 107 trappole, mantenendo inalterata l'estensione della superficie monitorata. Nel caso di Asossa, un ristretto numero di trappole è stato dislocato su di un'area più estesa e concentrato soprattutto nelle zone umide, considerate a maggior rischio di infestazione. La messa a punto di un sistema di monitoraggio efficiente è il primo passo operativo in un sistema di Adaptive Management della mosca tsé-tsé; tale approccio è stato impiegato a Luke dove ha prodotto una riduzione dei costi per la lotta, oltre che un calo delle popolazioni del dittero e della diffusione della tripanosomiasi.*

Parole chiave: *Adaptive Management, geostatistica, mappe di distribuzione, Etiopia.*

Introduction

During recent years, geostatistical analyses have increasingly been used for characterizing the spatial distribution of insect populations and planning Integrated Pest Management (IPM) strategies through the use of distribution maps (Brenner *et al.*, 1998; Fleischer *et al.*, 1999; Nansen *et al.*, 2003).
Spatial analysis on the basis of geostatistical methods applied to geo-referenced data relies on spatial variation to determine the degree of association and dependence of spatially related data (Davis, 1994). Such an approach allows to obtain additional information with respect other conventional statistics, that are not able to describe the spatial distribution in the sampling area or do not allow to correlate sample data with their spatial position.
Observations in space and time of insect occurrences and location of patches with increased densities (*hot spots*) are useful information for precision targeting pests in IPM projects. They also render operations cost-efficient and facilitate inclusion of communities as well as national institutions in project execution. These are important aspects of *Adaptive Management* (Baumgärtner *et al.*, 2004). Comiskey *et al.* (1999) regard adaptive management as a systematic, cyclical process for continually improving management policies and practices (tactics, strategies) based on lessons learnt from operational activities.
The aim of the present paper is to design a cost-efficient monitoring system on the basis of geostatistical analyses. This system is seen as the first step of an adaptive management system for tsetse (*Glossina* spp.) control in Ethiopia. Tsetse are vectors of trypanosome parasites (*Trypanosoma brucei*, *T. congolense*, *T. vivax*) that cause debilitating and often fatal diseases, known as trypanosomiasis, seriously affecting cattle health and productivity (Getachew Tikubet *et al.*, 2003; Sciarretta *et al.*, 2005).

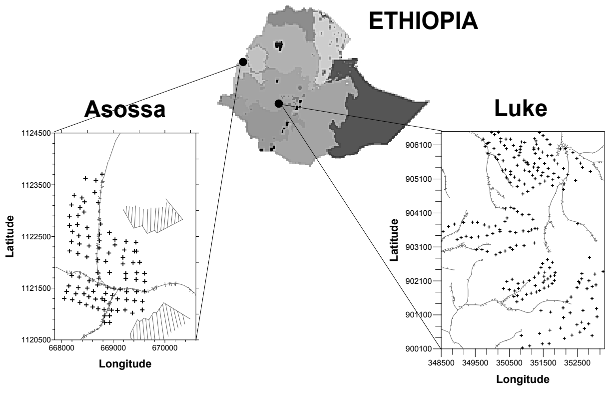

Fig. 1 - Geographic map of Ethiopia showing Asossa and Luke sites with trap position. Latitude and longitude are expressed as UTM coordinates.

Fig. 1 - *Mappa geografica dell'Etiopia con la posizione dei siti sperimentali di Asossa e Luke, per i quali è riportata anche la distribuzione delle trappole. La latitudine e la longitudine sono espresse in coordinate UTM*

Material and Methods

Study area

The Luke site is located in Cheha Woreda of Gurage zone (South-western Ethiopia) and covers about 50 km^2 of tsetse-infested area at altitudes ranging from 1,100 to 1,800 meters (Fig. 1). The Luke site is divided into three villages, whereby residential areas are located on the plateaus. The settlers from the respective villages use the low lands, which are tsetse-infested, for animal grazing and watering during the dry season. The vegetation in the area is characterized as woody savanna grassland with scattered acacia trees and thickets along rivers and streams, which are suitable habitats for tsetse populations.
The Asossa site is located in Benshangul Gumuz Regional State (Western Ethiopia) and covers about 6 km^2 of flat land at an altitude of about 1,500 meters (Fig. 1). Two villages are located near the study area, and the settlers from the respective villages regularly take animals to streams, which are tsetse-infested, for grazing and watering. The vegetation in the area consists of typical savannah grass land, dominated by bamboo and acacia trees along streams.

Monitoring operations

Monoconical traps of Vavoua version (FAO, 1992), baited with cow urine, were employed to analyze the spatial distribution of tsetse fly and design a monitoring system for obtaining information on tsetse occurrence in space as well as time. In general, the deployment of four odour baited traps per km^2 is recommended as a standard in tsetse control projects (FAO, 1992).
At the Luke site, we planned to deploy 250 traps with an approximate spacing of 250 meters within and 500 meters between rows. However, the qualities of the terrain did not allow the establishment of a regular grid. Instead, the 17 trap monitors walked and deployed 216 traps along paths producing a non-random distribution of traps in the area under study (Fig. 1). Traps were positioned in January 2003 and weekly collections were made during a one year period.
At the Asossa site, 97 traps were deployed in March 2003. Because of the relatively plain terrain, we were able to use a nearly regular grid with spacing of 250 meters within and 500 meters between rows (Fig. 1). Trap collections were done for 10 days, and tsetse catches were classified according to species.

Spatial analysis

Geostatistical methods generally include two main steps: a semivariogram analysis of the spatial structure of data and a surface interpolation to estimate the variable in unsampled locations.
Each sampling point is represented by three attributes: x and y, representing the spatial coordinates, in this case longitude and latitude in Universal Transversal Mercator (UTM) system, and z, representing the collected data, expressed as count number of individuals trapped.

Tab. 1 - Number of traps obtained from standard (complete) and reduced arrangements of monitoring traps at Luke and Asossa sites, Ethiopia.
Tab. 1 *- Numero di trappole impiegate nel corso dei vari disegni sperimentali adottati nei siti di Luke e Asossa (Etiopia).*

		Sampling arrangement											
		Complete	*33A*	*33B*	*33C*	*50A*	*50B*	*50C*	*PathA*	*PathB*	*66A*	*66B*	*66C*
Number of traps	*Luke*	216	138	141	153	107	103	113	109	117	74	-	-
	Asossa	97	64	64	64	49	49	49	-	-	32	32	32

The spatial dependence between sample units is usually represented by the variogram. On the abscissa, there is the distance between sampling points, while the ordinate represents the values of the calculated semivariance. The variogram is divided in several intervals or lags, that represent distance classes. The determination of the distance between traps can be calculated for all directions within the sampling space (omnidirectional variogram), used in this work, or for a particular direction (directional variogram).
A mathematical model can be fitted to the experimental variogram, so that the expression of the spatial dependence can be used to estimate values at points not considered in the sampling procedure. Such an estimate is obtained through an interpolation of z values and yields a grid that can be visualized as a two-dimensional map, called contour map, with contour lines representing equal z values. Contour maps were placed on a map showing the area under study and management.
The variogram analysis was carried out with Variowin software version 2.2 (Pannatier, 1996); interpolation of the observed values and mapping representation of data were made using the Surfer version 8.02 (Golden Software, Golden, CO, USA); AutoCAD Release 14.0 (Autodesk Inc., San Rafael, CA, USA) was used to set scale and coordinates of map showing the experimental area.

Adequate monitoring trap deployment strategy

In the past, variograms have rarely been used to assess the variance between spatially distributed samples and designing sampling plans, because the mutual dependencies of individual samples rendered difficult the use of traditional statistical methods.
However, Brus and de Gruyter (1994) showed that variograms can be seen as realizations of actual samples rather than model predictions and thus, the estimated variance is the only source of variance. In a design-based context, this observation opens the door to classical sampling theory applications (Cochran, 1977), including simple random sampling procedures, as used in this work.
The analysis follows closely Webster and Oliver (2001), who recommended that standard deviations obtained from different sampling strategies can be compared with those obtained from the original trap arrangement.
Reduced samples were obtained by eliminating traps from the complete arrangement at both the Luke and Asossa sites (Table 1):

- Reduction of trap number by 33%. The operation was repeated 3 times producing 3 reduced samples: *33A*, *33B*, *33C.*
- Reduction of trap number by 50%. The operation was repeated 3 times producing 3 reduced samples: *50A*, *50B*, *50C*.
- Reduction of trap number by 50% eliminating entire paths (for Luke only). The operation was done by eliminating every second path and produced 2 reduced samples: *PathA* and *PathB*.
- Reduction of trap number by about 66%. The operation was done one time for Luke (66A) and 3 times for Asossa, producing 3 reduced samples: 66A, 66B, 66C.

In Luke trap reduction of 33%, 50% or 66% was done inside each path. This because, due to the inaccessibility of some areas, trap arrangements were organized in rows corresponding to the paths covered by monitors during trap checks (Sciarretta *et al.*, 2005). At the Asossa site, traps to be eliminated were selected randomly from the entire sample.
For Luke, spatial analyses were applied to 2 data sets: the first consisted of data obtained from 18 January to 25 May 2003, while the second included the data collected from 5 October 2003 to 18 January 2004. For Asossa, spatial analyses were applied to the data obtained in March 2003.
For each trap arrangement, a variogram analysis was performed and standard deviation was calculated for each distance class interval. To evaluate the reliability of results, values and general trend of the standard deviations obtained from reduced trap arrangements were compared with those obtained from the original trap arrangement.
For each trap arrangement, maps of tsetse distribution were constructed. As interpolation method, we applied Surfer default setting of linear kriging with zero nugget, considered as adequate in defining foci of infestation in entomological samples (Brenner *et al.*, 1998). In fact, our main interest is the identification of hot spots rather than reliable population density estimates. Maps obtained from reduced trap arrangements were compared with those obtained from the original trap arrangement. To properly analyse the maps, two sources of error must be considered: missing of hot spots (i) and misrepresentation of some areas (ii). Both errors have practical conse-

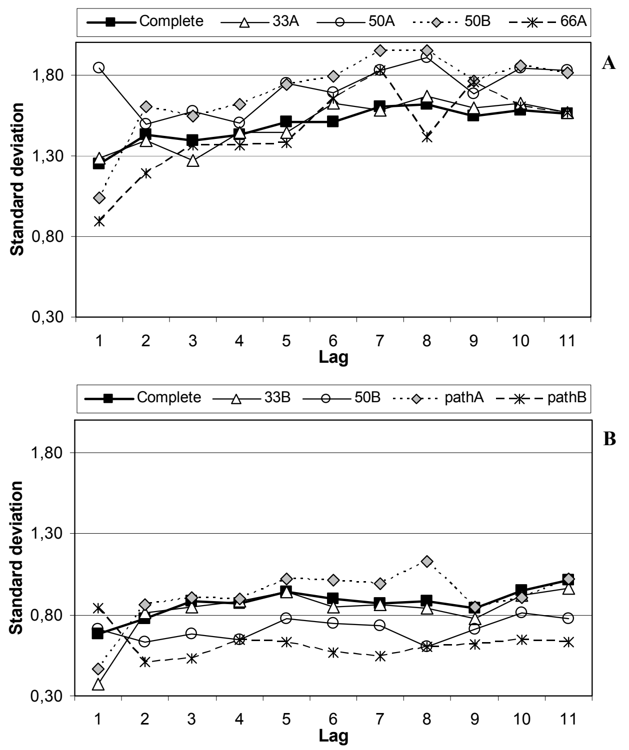

Fig. 2 – Standard deviation trends for variograms of the tsetse catches obtained from the complete and some reduced arrangements of monitoring traps at Luke: (A) period January 2003 - May 2003; (B) period October 2003 - January 2004.

Fig. 2 *– Andamento della deviazione standard, calcolata dai variogrammi delle catture ottenute dal disegno sperimentale completo e da alcuni pattern con numero ridotto di trappole nell'area di Luke: (A) periodo gennaio - maggio 2003; (B) periodo ottobre 2003 – gennaio 2004*

quences: i) can lead to a failure of the effectiveness of control measures, while ii) can lead to an excessive control measures, that would negatively affect the efficiency of the adaptive management strategy.

Results

At both sites, *Glossina morsitans submorsitans* Newstead was identified as dominant species; the occasional presence of *Glossina fuscipes* Newstead and *Glossina pallidipes* Austen was also recorded. In this paper, we refer to the combined number of these three species.

Luke site

Figure 2 shows the standard deviations of the omnidirectional variograms with 10 lags of 320 meters, calculated for the standard and reduced trap deployments at Luke. In both the first and the second data set, a 33% reduction of traps yielded similar variograms and reproduced the trend of the standard trap arrangement. Likewise, some arrangements obtained from the 50% reduction exhibited similar results (for example *50B*).

Figure 3 depicts the contour maps for each arrangement. In the first data set, arrangements *33A*, *33C* and *50B* gave the best representation, and only 1-2 small hot spots were not recognized, while in other arrangements, more hot spots were lost or misrepresented. In the second data set, arrangements *33A* and *33B* performed best, and all hot spots present in the complete arrangement of traps were observed. Also, arrangements *50A*, *50B*, *50C* and *PathA* resulted to a reliable representation (Fig. 3).

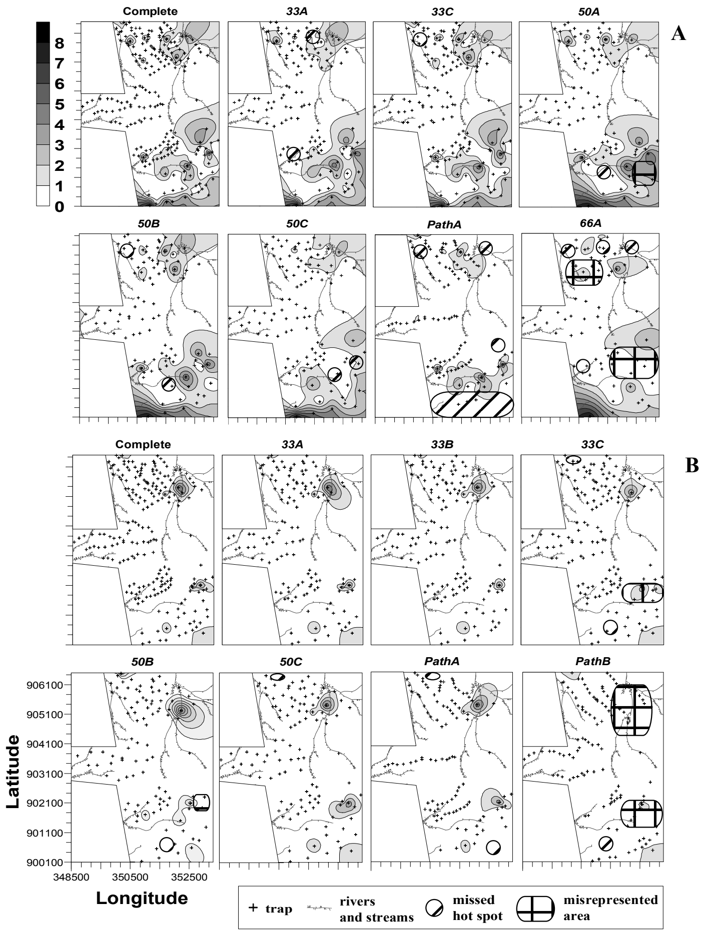

Fig. 3 - Contour maps showing the spatial distribution of tsetse, obtained from the complete and some reduced (33A, 33B, 33C, 50A, 50B, 50C, PathA, PathB, 66A) arrangements of monitoring traps, in the Luke site: (A) period January 2003 - May 2003; (B) period October 2003 - January 2004 (trap arrangements are explained in the text). Latitude and longitude are expressed as UTM coordinates.

*Fig. 3 - Mappe raffiguranti la distribuzione spaziale della mosca tsé-tsé (*Glossina *spp.) nell'area di Luke, ottenuta dal disegno sperimentale completo e da alcuni pattern con numero ridotto di trappole: (A) periodo gennaio - maggio 2003; (B) periodo ottobre 2003 – gennaio 2004. La latitudine e la longitudine sono espresse in coordinate UTM.*

Asossa site

Figure 4 shows the standard deviations of the omnidirectional variograms with 8 lags of 130 meters. The standard deviation of the sample from arrangements *33A* was very close to the one of the standard (complete) ar-

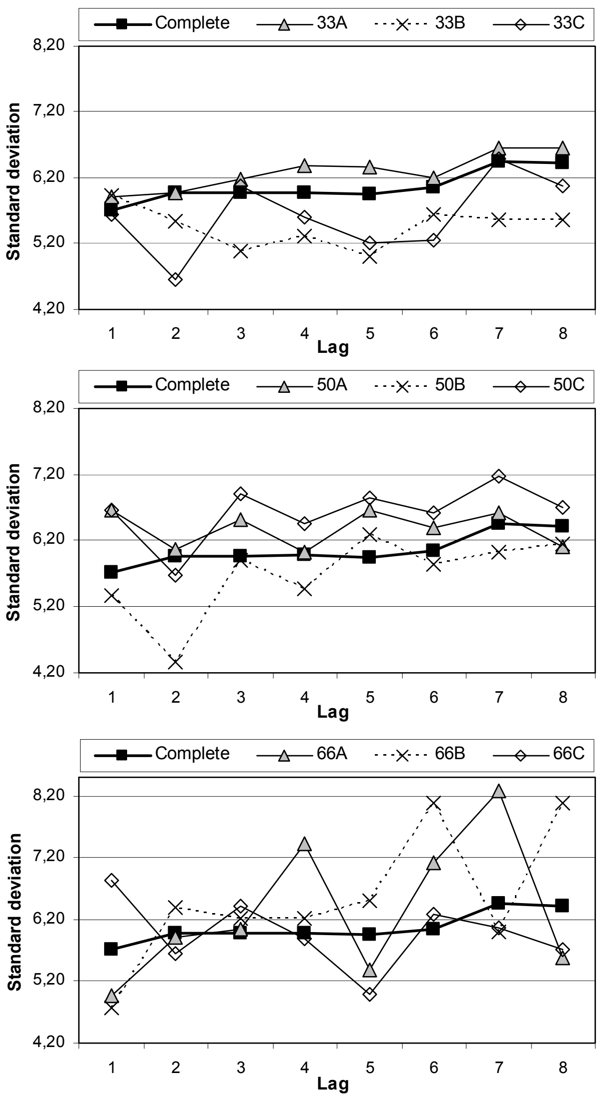

Fig. 4 – Standard deviation trends for variograms of the tsetse catches obtained from the complete and reduced arrangements of monitoring traps at Asossa, March 2003.

Fig. 4 *– Andamento della deviazione standard, calcolata dai variogrammi delle catture ottenute dal disegno sperimentale completo e dai pattern con numero ridotto di trappole nell'area di Asossa, marzo 2003*

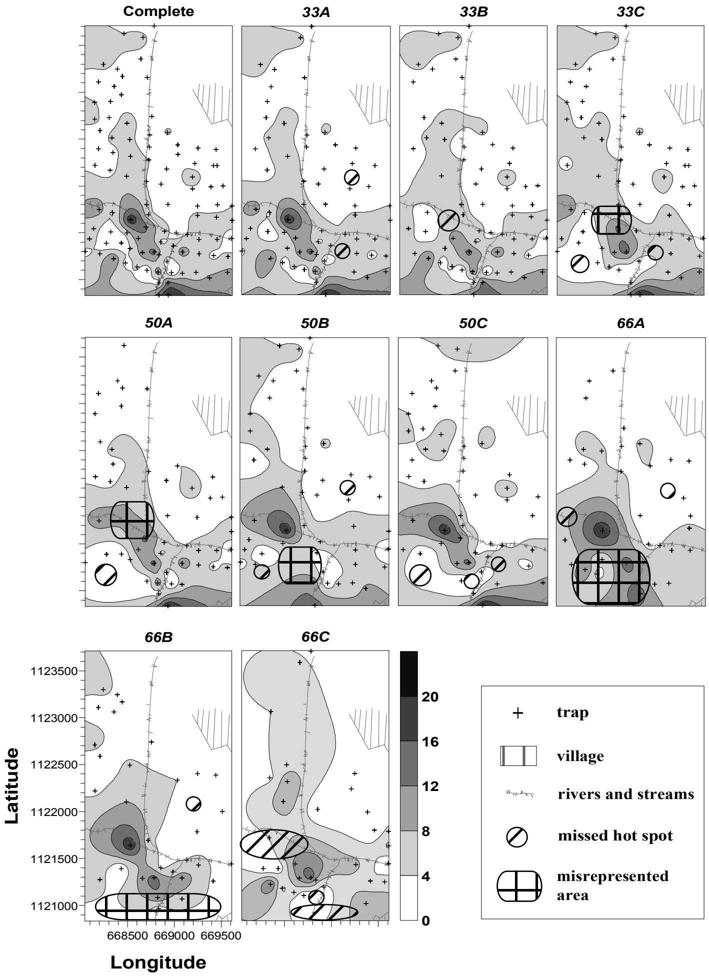

Fig. 5 - Contour maps showing the spatial distribution of tsetse, obtained from the complete and reduced (33A, 33B, 33C, 50A, 50B, 50C, 66A, 66B, 66C) trap arrangements of monitoring during March 2003, in the Asossa site (trap arrangements are explained in the text). Latitude and longitude are expressed as UTM coordinates.

Fig. 5 *- Distribuzione spaziale della mosca tsé-tsé (*Glossina spp.*) nell'area di Asossa, ottenuta dal disegno sperimentale completo e dai pattern con numero ridotto di trappole (33A, 33B, 33C, 50A, 50B, 50C, 66A, 66B, 66C): periodo marzo 2003. La latitudine e la longitudine sono espresse in coordinate UTM.*

rangement and displayed a similar trend. Also, arrangements *33B*, *50A* and *50C* showed similar results. However, arrangement *66A*, *66B* and *66C* produced erratic standard deviations.

Also in this case, contour maps were constructed for each arrangement (Fig. 5), indicating missing hot spots and the misrepresentation of some areas. Arrangements *33A*, *33B* and *50A* gave the best representation with only 1-2 small hot spots not recognized. However, arrangements *66A*, *66B* and *66C* produced maps of poor quality with inaccurate representation of observed distributions.

Discussion and Conclusions

According to the results, the arrangements obtained from a 33% reduction of traps performed best in both the variogram analysis and map representation. Nevertheless, the 50% trap reduction was considered as appropriate since it further reduced labour by still producing a satisfactory representation of tsetse spatial distribution.

For the Luke site, the arrangement 50B was considered adequate for the monitoring strategy and hence, the number of traps was reduced from 216 to 107, making available 100 traps for control and extension of the area under management (Sciarretta *et al.*, 2005).

The new deployment of traps was done in January 2004, and monitors inspected traps bi-weekly by walking along two paths. The remaining traps were used for hot spot control rather then for extension of the area under monitoring (Sciarretta *et al.*, 2005).

Cost-efficient monitoring of tsetse is the first step in the adaptive tsetse management program. Preliminary data show that this system is efficient in reducing tsetse and disease prevalence in cattle, increasing cattle productivity (milk production and calving rates) and making better use of land. For a complete illustration of the management strategy in Luke site, refer to Sciarretta *et al.* (2005).

At the Asossa site, the new sampling procedure with distances of 500 m x 500 m between traps allowed halving monitoring trap density. A first positioning of 84 traps in wet habitats was effectuated in April 2004, and inspections after 14 days showed limited hot spots occurrences (Fig. 6A). This indicates a possibility for further reducing trap numbers and extending the area covered. The new monitoring activities started in November 2004. The area covered by monitoring was extended to 20 km^2 and traps reduced to 72 (Fig. 6B). In these activities, the tsetse control teams followed the recommendation to reduce trap density for monitoring purposes but opted for a different trap arrangement strategy (Fig. 6). In the case of Asossa, we decreased trap density and extended the area under monitoring. This decision was influenced by high tsetse occurrences and vast extent of infested land.

At both sites, the geostatistical analysis provided reliable information on spatio-temporal tsetse occurrences and allowed detection of hot spots similar to the ones detected by the standard method. Likewise, no loss of information on hot spots occurred when reducing the number of traps.

More important, the method showed that the use of every second trap reduced labour costs involved in trap deployment, servicing and maintenance as well as tsetse counts, making the management system more cost-efficient than until now and thus, affordable by local communities.

Acknowledgements

We are grateful for financial support to University of Molise (Campobasso, Italy), BioVision Foundation (Zurich, Switzerland) and Swiss Development Corporation (Berne, Switzerland). The financial support provided by contributors to ICIPE's core funds and the logistic support by the Ethiopian Ministry of Agriculture (MOA) and the Ethiopian Social Rehabilitation and Development Fund (ESRDF) is greatly appreciated.

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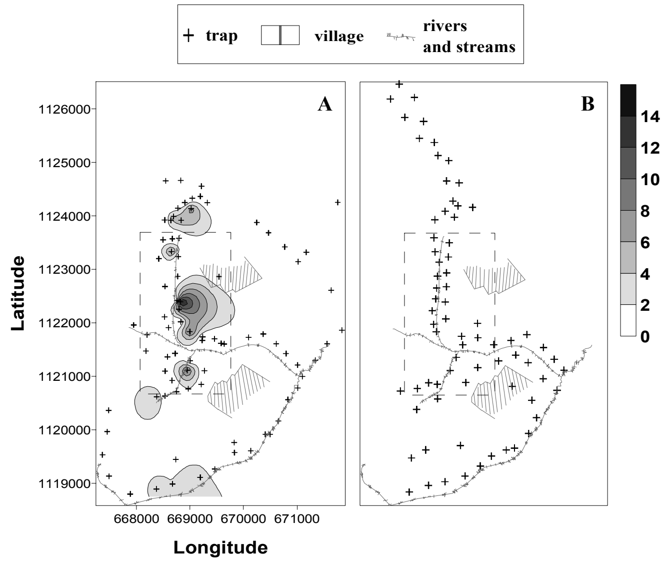

Fig. 6 – Experimental area (rectangles) at Asossa site. (A): trap position and contour map obtained from data of April 2004; (B): sampling area with trap positioned in November 2004. The dotted line represents the area covered by monitoring in March 2003.

Fig. 6 – *Rappresentazione grafica dell'area sperimentale di Asossa. (A): posizione delle trappole e catture ottenute dai dati rilevati nell'aprile 2004; (B): posizione delle trappole collocate nel mese di novembre 2004. La linea tratteggiata racchiude l'area monitorata nel marzo 2003.*

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